

PRICING ISSUES IN AVIATION INSURANCE AND REINSURANCE

Airlines are in the business of transporting passengers or freight from origin to destination as efficiently as possible. They do this with mixed financial success. However, they do it with remarkable physical success. The accident rate for airline travel is lower than for any other mode of transportation, and it continues to decline. Nevertheless, when accidents do happen they can cause considerable financial, as well as emotional, distress. Airlines choose to avoid the financial distress by purchasing insurance against loss-through-accident. Aviation insurers accommodate the desire of airlines to get rid of loss-due-to-accident by assuming *all* such losses. The remarkable thing is that the insurers have provided this cover on a ground-up basis for each and every loss, i.e., on an unlimited basis. The question such large and unlimited cover provokes is, how should it be priced?

To illustrate the magnitude of the problem, reflect back on the tragic events of 9/11. On that day United Airlines and American Airlines each lost two aircraft to terrorism. The insurers covering those two accounts faced the prospect of claims for a) loss of hulls, b) liability for passengers and crew, and last but by no means least, c) liability for on-the-ground third party fatalities. Worse, at one time during the harrowing hours of that day, as many as eight other planes were thought to be under the control of terrorists, with the prospect of financial losses several multiples of what was already known. One month later American Airlines insurers faced another (unrelated) loss over Queens. Airclaims, the aviation loss adjuster, gives “[a] provisional estimate of incurred aviation losses in 2001 [as] just

under \$5.8 billion”¹. This was more than twice the previous worst year, \$2.3 billion in 1994, even if adjusted for inflation, etc. (Ironically, absent the 9/11 events, 2001 was one of the best safety years ever.) To cover these claims Swiss Re estimated world wide premiums for 2001 of \$1.9 billion.² Losses would have to be paid out of capital or higher future premiums.

The insurers responded quickly to correct the cost of insurance that was immediately seen to be drastically under priced, given the exposures assumed. Swiss Re suggests that the premiums for 2002 would be in the range of \$4-5 billion. In addition, the “price” of insurance was raised indirectly by changing coverage terms. Terrorism was excluded as a cause of loss and third party coverage was limited to \$50 million. Terrorism coverage has since been reinstated and/or assumed by various government programs. The question nevertheless remains, what is an appropriate price for aviation insurance coverage? What capital is necessary and what return should insurance capital providers expect?

The Terms of Aviation Insurance

Airlines buy insurance to cover both hull loss and liability exposure on a twelve month basis. Until recently, typical amounts might be a \$250 million limit for hull loss and a \$1.5 billion limit for liability. Since 9/11, demand for higher liability limits has increased and the introduction of larger Airbuses in the near future will cause demand for higher hull limits. These limits apply for *each aircraft, each and every loss*. The policies

¹ The Airclaims Aviation Pocket Handbook. Airclaims, 2002.

² Flight to Quality – Financial security in the aviation insurance market, Swiss Re, September 2002.

are said to be “all risks” policies although all policies contain some exclusions. Similarly, the policies can be viewed as a ground-up coverage although small deductibles may apply in practice. The significant point is that stated limits apply to each hull or each event, but in total the coverage applies to the whole fleet and to multiple occurrences within the fleet. In short, the insurer’s exposure is unlimited. The insurer’s premium is not, neither is their capital.

If a single accident totaled the limits, insurers would, under the above numbers, have to pay claims of \$1.75 billion. In other words, insurers in 2001 collected premiums (\$1.9 billion) sufficient to cover 1.1 full limit losses per year. Even at the elevated levels of 2002 premiums, only 3 full limit losses are covered annually. World wide aviation accidents occur at a rate of approximately two per month, even though few are full limit losses. The potential exposure is huge compared to premiums collected.

Aviation Exposure

As of 2001 there were approximately 15,000 western built jets and 8,000 turboprops in annual scheduled airline operation. Those planes move 1.6 billion passengers in 21.5 million departures each year.³ Swiss Re estimates the total exposure from hulls alone is \$550 billion. And, as observed, liability limits are several times as great. Clearly, premium collected is tiny compared with total “sums insured” exposure. However, viewing the exposure on this basis, while dramatic, may not be helpful. Airplanes are, after all, not likely to all fall out of the sky in concert.

To gauge the true exposure, underwriters use a combination of envisioning worst case scenarios of exposures together with historical experience. For example, even though the events of 9/11 are unlikely to be repeated, it is still possible for multiple hulls to be lost and huge loss of life to take place in a disaster

³ 2001 IUAU Statistics

scenario where an accident occurs at a major airport destroying several fully loaded planes on an active taxiway.

The 9/11 loss therefore represents a marker of what is possible.⁴ Hopefully, it is a marker that is very unlikely to occur. “How likely?” is a question of risk estimation rather than exposure measurement.

Table [1] below summarizes the history of accidents 1980 to 2001.⁵ Actuaries and statisticians can examine this data and its components in depth and use it to develop a risk model characterizing both the amount of exposure and likelihood of loss from aviation accidents. Using history to project into the future is a difficult science. Perhaps it is more of a scientific art. For example, events that happened twenty years ago will have to be translated into current dollars, but they should, ideally, also be adjusted to the current technological, economic and judicial environment. A passenger liability settlement from 1980, even if put in current dollars, would be much less than one that would be required today. “Settlement creep” factors should be used to adjust the data.

⁴ In this scenario, the excess third party liability beyond \$50 million would inure to the airlines, or airports, under new terms and conditions.

⁵ Data provided by Global Aerospace and describes all losses greater than \$10 million.

Historical Losses 1980-2001, Fully Developed. Underwriting Year Basis, Including WTC.

Developed Factor 5%	Number of Losses	Annual Event Losses
Total (Indexed to 1999)	351	\$35,128
1980	2	\$347
1981	2	\$160
1982	8	\$1,253
1983	11	\$1,370
1984	3	\$183
1985	13	\$3,148
1986	5	\$233
1987	10	\$1,465
1988	9	\$1,805
1989	18	\$2,096
1990	12	\$1,967
1991	19	\$1,227
1992	16	\$1,262
1993	28	\$1,614
1994	31	\$2,930
1995	22	\$1,281
1996	20	\$2,254
1997	32	\$1,411
1998	29	\$1,817
1999	29	\$1,667
2000	21	\$1,117
2001	11	\$4,521
Average (1980-2001)	16.0	\$1,597
Standard Deviation	9.7	\$1,022
10 Year Average (1992-2001)	23.9	\$1,987
Standard Deviation	7.0	\$1,042

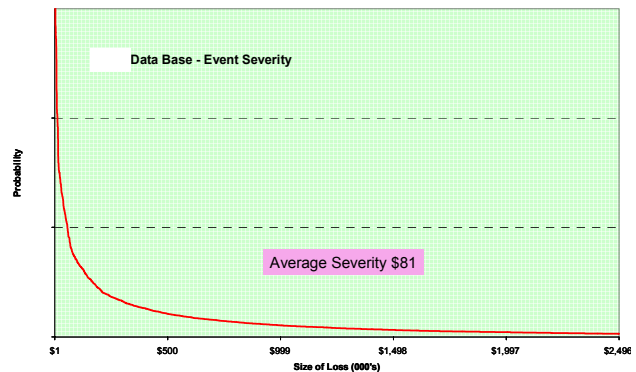
Table 1

Typical risk modeling approaches will involve examining the annual frequency of events and a separate study of the severity of accidents. Once separate frequency and severity models are developed a simulation can take place to assess the risk insurers face. Exact estimation of the risk model is not the subject of this paper. Pricing is. Nevertheless it is impossible to adequately discuss pricing without some form of risk or uncertainty model. In what follows we have used a fixed set of 20,000 annual scenarios that have been generated

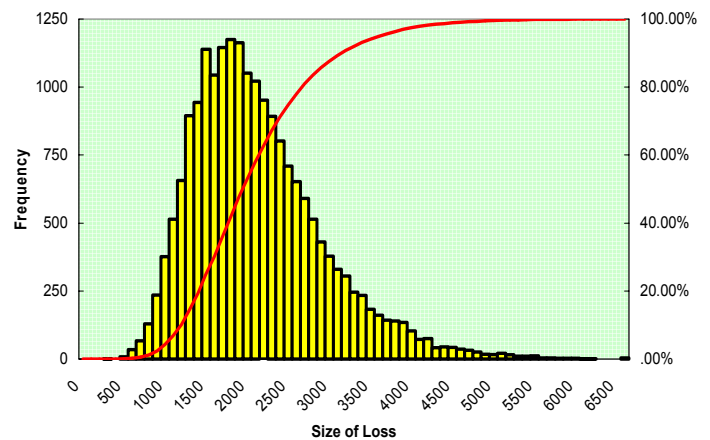
Characteristics of the 20,000 Scenario Fixed Data Set*

Expected Annual Losses	\$2,079	per Year
Standard Deviation of Losses	\$799	per Year
Maximum Aggregate Losses	\$6,877	
Maximum Individual Event Loss	\$2,500	
Expected Frequency of Losses	25.7	per Year
Expected Severity of Losses	\$81	

* Assumes an inflation adjustment of 5% p.a.



Aggregate Potential Losses 20,000 Year Data Set



from a proprietary risk model⁶ to make price comparisons. A fixed set of scenarios is not as robust as a full Monte Carlo simulation (which will actually produce multiple 20,000 year or greater sets of scenarios) but is equally valid from a comparative point of view. More important are the characteristics of the data. It is detailed in Figure [1] below. Figures [1B] and [1C] illustrate the severity assumptions and the annual aggregate losses resulting from the frequency and severity assumptions contained in the table. As an illustration of the nature of the risk, the scenario set shows that there is one in eight chance that aggregate annual losses will exceed \$3 billion.

⁶ Provided by Global-Aerospace, the scenarios were generated by Willis Re.

Pricing

If an insurer were to insure the whole aviation industry, what price should it charge? Traditional approaches might be to charge expected losses plus some premium to cover overhead, brokerage and some profit margins. Given the aggregate numbers above, the industry premium would be \$2,079 million plus overhead etc. Setting the overhead, etc., to zero the premium would be exactly \$2,079 million.

This is not exactly the same as pricing at “burning cost”, but it is a forward looking version of it. (Remember, the suitably adjusted ten year historic burning cost is \$1,987 million.)

A consequence of pricing at expected losses, if the expectation estimate is an accurate one, is that underwriting profits will be made approximately half the time and underwriting losses the other half. This is not the reason investors enter into the risky world of insurance! It would be acceptable behavior, perhaps, if the profits when they occur were much greater in magnitude than the losses. Sadly, this is not the case. In insurance it is usually the reverse, with limited upside profit and unlimited (or at least vastly greater) downside losses.

There is no agreed upon theoretical method for pricing insurance risk. Several approaches have been designed but none can claim ascendancy over another. The feature that is most agreed upon, however, is that the price should contain elements of “load” related to the riskiness of the subject insurance. (This would be in addition to overhead, etc., that we have herein assumed to be zero).

One of the most recognized measures of risk is the standard deviation of outcomes.

Using this, Rodney Kreps⁷ has theorized that an appropriate pricing formula is

$$\text{Price} = \text{Expected Loss} + \text{Load}$$

Where

$$\text{Load} = [\text{Fraction}] * [\text{Std Dev}]$$

More formally,

$$P = EL + \gamma * \sigma$$

EL is Expected Loss, and γ is the fraction of σ , the standard deviation. [Astute readers will also note the similarity to the capital market’s Sharpe Ratio, where $\gamma = (P - EL) / \sigma$.]

Given the fixed data set, if $\gamma = 100\%$ then the industry should pay a premium of,

$$\begin{aligned} P &= \$2.079 + (1.0) * (\$799) \\ &= \$2,878 \text{ million.} \end{aligned}$$

Similarly if $\gamma = 150\%$ the premium should be \$3.278. [γ is often referred to as the mark up.]

We can also look at the situation in reverse. If the industry in 2003 was charged total premium of \$3,400 million then the implied load was $\gamma = 165\%$.

⁷ See Kreps, R. E., 1999, “Investment-Equivalent Reinsurance Pricing”, in O. E. Van Slyke (ed), *Actuarial Considerations Regarding Risk and Return in Property-Casualty Insurance Pricing*, pp. 77–104, (Alexandria, VA: Casualty Actuarial Society). (This paper was awarded the CAS Dorweiler Prize).

Several comments are in order. First, the conclusions about load and mark-up of the risk are *relative* to the fixed scenario set. Persons with a different view of the riskiness of the aviation world will have different views of expected loss and mark-up percentages γ . And, since no single independent or standardized risk model exists, comparisons of price *levels* can be problematic.

However, the reverse observation, the implied γ can still be used to some advantage for *relative* pricing. If price comparisons are made between one insurer to another (or between insurer and reinsurer, between one program and another) with the *same* data set, then deductions about implied γ can gauge relative conservatism or cheapness. Examples of this will be provided below.

A second observation is that although a fixed data set is used here for illustrative purposes it is neither recommended as accurate nor endorsed as appropriate. For example, the data set has a standard deviation of \$799 million. The historical data in Table [] shows historical deviations of more than \$1 billion. Now, to be sure, the history contains the 9-11 disaster but it cannot be ignored. Counting it in the sample as one in twenty two of the observations probably exaggerates its likelihood of recurrence, but the fixed set implies the probability of a year like 2001 as about one in one thousand, which is probably too low. Notwithstanding, the data set remains extremely valuable especially for comparison purposes.

A third observation concerns the pricing models. The Kreps model is the simplest model for credible risk pricing. It is not the only one. Kreps with a

colleague, John Major,⁸ has also investigated another form.

$$\text{Premium} = \gamma (\text{EL})^\alpha$$

And

Lane⁹ has investigated a power function that relies on both frequency and severity.

$$\text{Premium} = \gamma * (\text{Frequency})^\alpha * (\text{Severity})^\beta$$

Both of these formulas require multiple observations to establish parameter fits, and may not be appropriate in this aviation context. However, all have proved useful comparison tools in the context of Cat bonds. Parameter estimates from fits to the pricing of these other insurance risks can also be a useful cross check to see how aviation prices stack up.

⁸ Kreps R E. and Major J. M. "Reinsurance Pricing" in Lane, M, ed., 2002, *Alternative Risk Strategies*, (London: Risk Books), Chapter 10.

⁹ Lane, M. N., 2000, "Pricing Risk Transfer Transactions", *ASTIN Bulletin*, 30, (2), 2000, pp. 259–93 [This paper was awarded the 2000 CAS Hachemeister Prize].

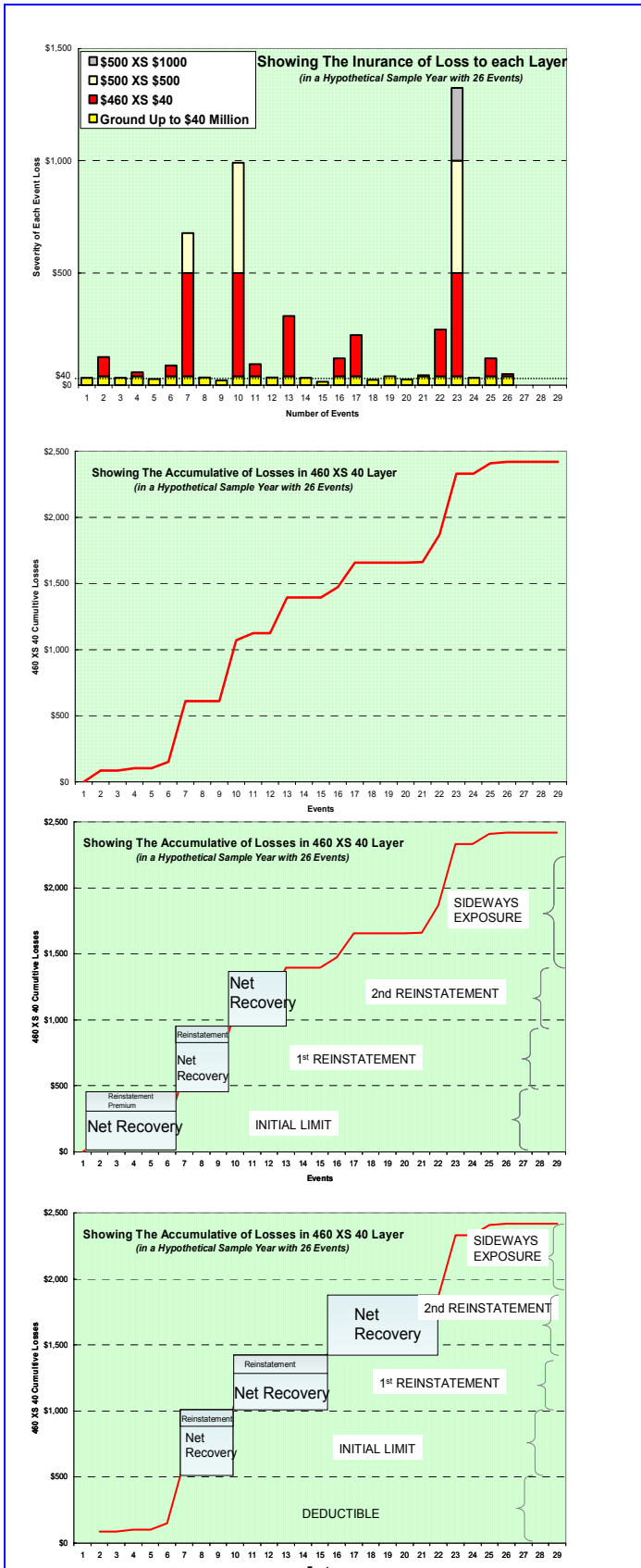
Reinsurance

Reinsurance of aviation risks is done on an aggregate excess of loss basis (AXoL) rather than a more familiar excess of loss (XoL) basis. This is necessary because insurers require coverage for the aggregation of multiple events each year. Reinsurers do not, however, provide unlimited coverage for any number of events. Typically, the reinsurers will provide a single aggregate limit of coverage with one or two reinstatements.

AXoL works as follows. On a per event basis, reinsurers agree to reimburse all losses above an agreed attachment point up to a specified limit. This limit can be exhausted by the aggregation of several events that each penetrate the layer, but do not individually exhaust it, or it could be penetrated by a single large event that went through the limit itself. The aggregation of event losses to the layer is depicted in Figs [3A and 3B].

If the agreed limit is exhausted there are typically one or two reinstatements. Once reinstated, the second or third limits act as the first. Reinstatement premiums have to be paid, and this is done on a “pay as paid” basis. In other words, as claims are paid a fraction of the reinstatement premium is withheld from the claim. Naturally, as the limit is exhausted the full reinstatement premium for the next limit will have been paid. But equally, if the first limit is not exhausted some fraction of an unutilized reinstatement limit will have been paid for unnecessarily.

Certain reinsurances will also be structured to include profit commissions payable back to the insured for non use. Alternatively, no-



claims bonuses may be part of the transaction instead of profit commissions.

All the other paraphernalia of reinsurances may be available including additional premiums, deductibles, risk or clash covers. For example, the lower two panels of Fig [3] shows two conventional reinsurances, one with no deductible, the second with a deductible equal to the first limit.

The important point is that reinsurances also contain price information that the insurer can consider in appraising the array of proposals that he will have to consider. To say that insurers need to consider the cost of reinsurance in pricing insurance is somewhat banal. What is being asserted here is slightly more important. If a reinsurance proposal is deconstructed into its expected value and load, and the load is deconstructed as a mark up and risk (standard deviation) the insurer can see how the reinsurer views and values the risk. This is a form of reverse engineering that can inform the pricing of the underlying insurance.

Assume that a specific proposal is evaluated on the same 20,000 scenario set that is used for the reinsurance. After all, this is what the insurer thinks captures the risk he is taking. It must necessarily characterize the risk he is getting rid of to the reinsurer.

Now if the price of insurance is 100% of the standard deviation assumed and the price of reinsurance is 150% of standard deviation ceded, then one of two conclusions is possible. Either the insurance is priced too low relative to the reinsurance, or the reinsurer sees a much riskier world than is captured by the 20,000 scenario set. Further, if *every* reinsurer presented a proposal that was

say 50% higher then one is driven to the second conclusion – the insurer is underestimating the risk.

Equally, if the reinsurance proposals all cluster around the same mark-up, say 100% + or – 25% of standard deviation, one could perhaps deduce that competitive forces are keeping prices tight, but that within the range certain proposals will be cheaper than others – i.e. those with mark-ups at 75% instead of 125%.

Load relative to risk (the mark-up) is not the only measure to discriminate between alternatives. Others measures might include load to limit or the best case/worst case ratio. The mark-up is, however, the most important since it is a measure that affects profit directly and can be measured on both sides of the balance sheet.

Insurance vs Reinsurance

Aviation insurance is written on an unlimited basis, reinsurance is written with strict limits of liability. This mismatch is not the only difference.

Reinsurance covers the event loss and therefore inures to product manufacturers as well as airlines. The cause of loss of an aviation accident can fall on the airline, because of pilot error for example, or it can fall on a manufacturer, because an engine fell off. The reinsurance is paid to reimburse the settling party. Obviously, the limit applies to total payments – airline or manufacturer. This is not a problem for analysis as long as the data set is constructed to cover all accidents on a consistent basis. Also, it is worth noting that in contrast to airline insurance, manufacturer's insurance does usually contain a specific aggregate limit of

liability, typically around \$1 billion per year.

Reinsurance is written on a layered occurrence basis, insurance is written ground-up. This can cause a problem for the deconstruction (of expected loss and risk load relative to volatility) exercise suggested above.

The issue is illustrated in Fig [4] below. In looking at the ground up risk it is relatively easy to unscramble expected loss and load (given the fixed data set). It also easy to measure load as a fraction of standard deviation.

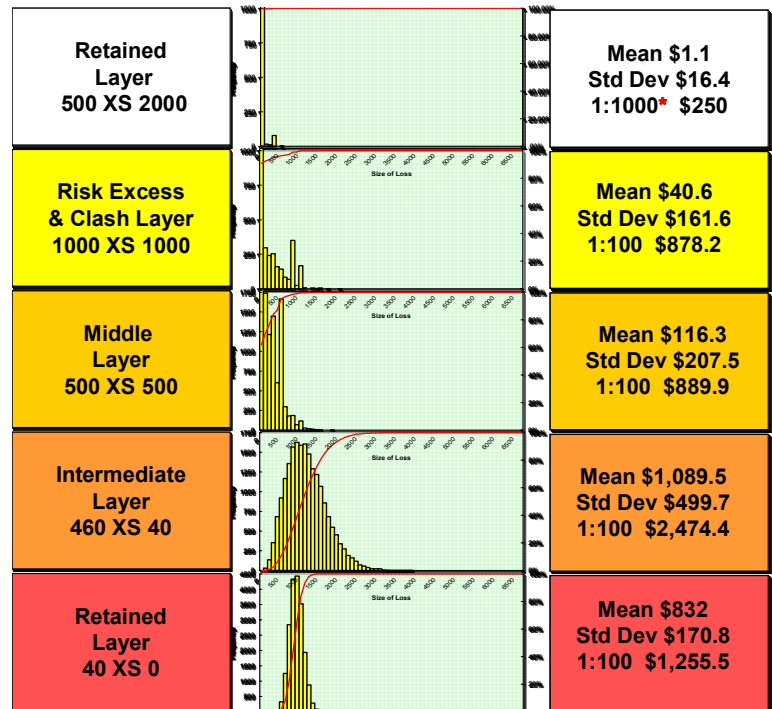
Now to compare with reinsurance, the fixed data set must be broken into layers, in particular to the layers used by the reinsurers. A generalized set of complimentary layers is shown in Fig [4], together with the exposure statistics of each layer.

Since the whole data set is broken into layers, the sum of the expected values of all layers is equal to the expected value of the industry data set treated as a single layer. Readers may wish to check that the layered sum is equal to the aforementioned \$2,079.

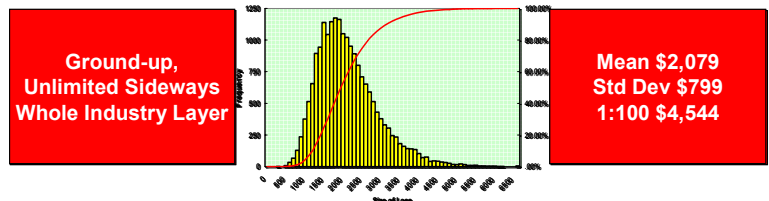
The same cannot be said of the volatilities. Standard deviations are not linearly additive. The sum of the layer volatilities will be greater than the volatility of the whole layer. Necessarily therefore, the mark-up of volatilities of all layers will be *less* than the mark-up for the whole layer, if one tries to equate loads. Remember this is important because we are trying to equate pricing approaches and extract consistency of mark-up. If reinsurance mark-ups are higher it again underscores the inadequacy of insurance pricing.

Put another way, if both insurers and reinsurers marked-up their expected losses by 100% of standard deviation, and if it were possible to reinsure all layers completely, the cost of reinsurance would exceed the premiums

GENERALIZED REINSURABLE LAYERS OF EXPOSURE



WHOLE INDUSTRY, DATA SET CHARACTERISTICS



from insurance. Fully reinsured aviation insurance would be losing proposition. Obviously the insurer would have over-reinsured.

Intuitively, over-reinsurance can be seen another way. The level of insurance can be viewed as covering, say, losses in 99 years in one hundred. If each layer is reinsured at the same (1:100) level then the insurer is

effectively now reinsured to say one in a million. (The exact number will depend on the number of layers, correlations etc). The ultimate insured benefits, but is not paying for the benefit. The investors in the aviation insurer who did this would be the guaranteed losers. The aviation insurer would be subsidizing the insured.

Given that reinsurance is not available on an unlimited basis the above circumstance is at best theoretical. However, it is hopefully instructive. Any time the deconstructed price of reinsurance is higher than the deconstructed price of insurance, given the same data set, it is a warning flag that some form of subsidy or cost is embedded in the operation.

The other consequence of the coverage discrepancy between insurance and reinsurance is that however much is actually reinsured, it is impossible to be fully covered. There is always going to be some residual sideways exposure retained by the insurer. It is important that the insurer recognize that and allow for it in its capital calculations.

Return on Equity

Reinsurance is a powerful source of capital for the aviation insurer. But as noted it can be an expensive one. The cost of reinsurance must be evaluated along with other forms of capital to maximize return on equity. Return on equity is, of course, a ratio – expected profit divide by equity. Its calculation depends on a numerator and a denominator. The numerator can be well handled by Mr Kreps’ very useful pricing formula. The denominator may depend on capital allocation rules.

To illustrate,

Expected Profit =

$$\text{Premium} - \text{Expected Losses}$$

And $\text{Premium} = \text{EL} + \gamma * \sigma$

Therefore

$$\text{Expected Profit} = \gamma * \sigma.$$

Calculating equity on the other hand requires knowing exactly how much it is, or in a world of allocated capital, how much is allocated. Suppose the capital rule is to provide enough capital to cover losses in 99 years out of 100. And suppose that that $\gamma = 100\%$; then for the industry as a whole, on an un-reinsured basis, the return on equity capital is as follows:

$$\text{RoE} = \frac{\text{Expected Profit}}{\text{Allocated Equity Capital.}}$$

i.e. $\frac{\$799}{\$4,544}$
 $= 17.6\% \text{ p.a.}$

The chances of making a profit can also be calculated. With this data set it will be of the order of 85%.

Now lets illustrate the cost of capital from the insured’s point of view. Coverage from a provider with allocated capital to cover 99 cases out of 100 is like investing in a BB+ bond - it is sub investment grade. To feel secure that insurance will be recoverable the insured could buy credit default insurance at some extra cost. Or he could require the insurer have more capital allocated to aviation. [Assume that this is visible directly, or indirectly via ratings.] The

consequence for the insurer is that the return on the larger capital allocation would fall – unless he received a higher premium.

Consider if capital was allocated at the 1: 1000 level. This is about the level of an AA- rated bond. Then the RoE calculation would be,

$$\$799/\$5,542.9 = 14.4\%$$

[\$5,542.9 is from the 1:1000 level in the data set]

To maintain a 17.6% RoE

Profits would have to increase to

$$\$975.5$$

An extra \$175 million profits is required for the devotion of approximately an extra \$1 billion of capital. It seems exorbitant. Indeed it is. But it is the natural consequence of a) the insured requiring a high rating, b) the insurer trying to maintain the RoE, *and* c) the only source of capital being equity.

Reinsurance and debt capital may be cheaper. Then again they may not. Consider the alternatives of buying reinsurance or borrowing to increase capital to the 1:1000 level. Extra debt at the BB+ level may cost LIBOR plus 700 basis points. Therefore a \$1 billion loan will cost \$70 million¹⁰. The return on equity now reads

Expected Return

$$= (\$799 - \$70) / \$4,544$$

¹⁰ LIBOR – the risk free investment return on capital is left out of these comparisons. It would be the same for all.

$$= 16.0\%$$

This is higher than the 14.4% - so debt would be cheaper capital.

Now consider reinsurance, which for the sake of illustration we will assume is available on a no-limits basis at the 1000 XS 1000 layer. Fig [4] shows that the standard deviation of this layer is \$161.6, and if it is priced at 100% mark-up as the insurance is, then the return calculations are,

Expected Return on Equity

$$= (\$799 - \$161.6) / \$4,963$$

$$= 12.8\%$$

[With the purchase of the 1000 XS 1000 full reinsurance layer, 1:1000 capital level has increased from \$4,544 to \$4,963, rather than to \$5,544 without the layer. Notice that the true cost of reinsurance is the load. The monetary outlay includes the expected loss, which is then also picked up as a benefit.]

Given this example the alternative capital structure answers may now be arrayed as follows

Return on Equity, when capital is provided to the 1:1000 level, is

All Equity	14.4%
Equity and Reinsurance	12.8%
Equity and Debt	16.0%

Clearly reinsurance is a more expensive alternative, given a mark-up of 100%. This underscores again that the insurance mark-up needs to be higher than the reinsurance mark-up.

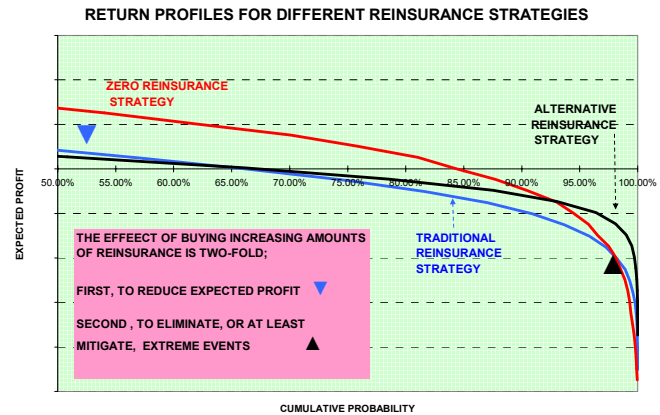
This is a highly idealized and somewhat impractical analysis. Not least of the reasons being that reinsurance is not available as described. Debt may not be available either. Also, as previously indicated the data set may not be conservative enough thereby overstating the *level* of returns. And at other points in the cycle conclusions may reverse. Once again however the example is hopefully instructive and can show relative pricing behavior.

The example suggests that it may be advantageous to take reinsurance and debt into the insurer's capital structure on occasion. But, it is equally easy to see that the results are quite sensitive to the relative cheapness or dearness of the reinsurance and debt. Then again, reinsurance may be at times the only source of extra capital. When this is the case, better change the price of insurance to keep the capital suppliers happy.

Conclusions and some Reinsurance Strategy Trade-Offs

The application of a simple pricing rule that links the price of insurance to risk has led to some powerful insights. Not only can it be applied to both sides of the balance sheet, it can be used to deconstruct prices offered by others, thereby making complicated offerings more transparent.

The same methodology can be used at the operational level to discriminate between competing reinsurance proposals. While detailed consideration is beyond the scope of the present paper we close with a diagram, Fig [5], showing how comparisons can be made that take into account preferences not captured by simple expectations. Two such strategies are



shown. The underwriter can now examine the profile most appropriate to the capital providers in addition to their desire for high expected returns on equity. Just like the capital structure question itself, trade-offs are necessary. Optimal choices are beautiful things but they cannot be achieved without honest pricing, deconstructing and evaluating all the possibilities.

